STATEMENT OF ACCURACY OF TRANSLATION

I, the undersigned, hereby declare that the annexed document is accurate English translation of the below-identified document, that the translation was duly made by me, and that I am fully familiar with both English and Japanese, for which I will assume any responsibility:

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[Title of the Document] Claims for the Patent

[Claim 1]

A vibration wave driven apparatus comprising: a driven member; and a vibrator consisting of an elastic member in contact with said driven member at a plurality of contact parts formed on one surface and an electromechanical conversion element of a flat plate-like shape joined to the other surface of said elastic member, characterized in that said plurality of contact parts are located on the same surface as the one surface of said elastic member.

[Claim 2]

A vibration wave driven apparatus according to claim 1, characterized in that the vibrator has a substantially rectangular plate-like shape, and said one surface has substantially the same shape and size as said vibrator.

[Claim 3]

A vibration wave driven apparatus according to claim 1 or 2, characterized in that said elastic member is formed from a metal plate material by press punching or by an etching process.

[Claim 4]

A vibration wave driven apparatus according to any one of claims 1 to 3, characterized in that said electromechanical conversion element comprises a laminated piezoelectric element having piezoelectric

materials and electrode materials alternately laminated one upon another.

[Claim 5]

A vibration wave driven apparatus according to any one of claims 1 to 4, characterized in that said elastic member includes notches or recessed parts for adjusting vibration characteristics of the vibrator formed therein at a plurality of locations thereof.

[Claim 6]

A vibration wave driven apparatus according to any one of claims 1 to 5, characterized in that said elastic member has a supporting member integrally formed thereon, for supporting the vibrator.

[Claim 7]

A vibration wave driven apparatus according to any one of claims 1 to 6, characterized in that said electromechanical conversion element excites said vibrator in out-of-plane primary and secondary bending vibration modes having different directions from each other, and said plurality of contact parts are formed in a vicinity of loops of said primary bending vibration modes and in a vicinity of nodes of said secondary bending vibration modes.

[Claim 8]

A vibration wave driven apparatus according to any one of claims 1 to 7, characterized in that said contact parts have a space formed in a surface thereof

opposed to said electromechanical conversion element.

[Claim 9]

A vibration wave driven apparatus according to any one of claims 1 to 8, characterized in that at least a part of said driven member is provided with a magnet.

[Title of the Document] Specification

[Title of the Invention] VIBRATION WAVE DRIVEN APPARATUS

[Technical Field]

[0001]

The present invention relates to a vibration wave driven apparatus. In particular, the present invention relates to a small linear type ultrasonic motor.

[Background Art]

[0002]

As a conventional ultrasonic motor implementing vibration wave drive, there have been proposed motors some of which use a square bar-like or square plate-like vibrator having projections (for example, see Patent Document 1) and others of which has a vibrator that has contact parts instead of projections (for example, see Patent Document 2).

[0003]

The former ultrasonic motor includes, as shown in FIG. 12, a vibration plate 51 which has one surface thereof formed with projections 52a and 52b, piezoelectric elements 53a, 53b, and 53c provided on the other surface of the vibration plate 51; and a driven member 55 disposed in contact with the projections 52a and 52b. The piezoelectric elements 53a, 53b, and 53c excite the vibration plate 51 to generate vibrations in a stretching vibration mode and

a bending vibration mode. The projections 52a and 52b are disposed at the loops of vibrations in the stretching vibration mode or in the vicinity thereof so that the tip ends thereof make a repeating motion in a direction indicated by "X" in FIG. 12. The projections 52a and 52b are also disposed in the vicinity of the loops of vibrations in the bending vibration mode so that the tip ends thereof make a repeating motion in a direction indicated by "Z" in FIG. 12. Vibrations in the stretching vibration mode and vibrations in the bending vibration mode are combined to cause the tip ends of the projections 52a and 52b to make a substantially elliptic motion. A feeding force caused by this substantially elliptic motion moves the driven member 55 relative to the vibration plate 51 in the direction indicated by "X" in FIG. 12.

[0004]

The reason why the vibration plate 51 has the projections 52a and 52b that are disposed at loops of vibrations in the stretching vibration mode or in the vicinity thereof and are also disposed in the vicinity of loops of vibrations in the bending vibration mode is that contacting of the driven member 55 with the vibration plate 51 at a position other than these positions causes an inconvenience such as abnormal noise or reduced output.

[0005]

As shown in FIG. 13, the latter ultrasonic motor includes a rectangular flat vibration plate 61, which is substantially smooth without no projection or recessed portion, supported by four stays on a base 60, a piezoelectric element 63 provided on one surface of the vibration plate 61 at one end portion 62 thereof, and a driven member 65 disposed in contact with the other surface of the vibration plate 61.

[0006]

The piezoelectric element 63 induces primary out-of-plane bending vibrations in the vibration plate 61 to deform the vibration plate 61. A feeding force caused by this deformation moves the driven member 65 relative to the vibration plate 61 in a direction indicated by the arrow in FIG. 13. This vibration plate 61 has no projection and thus is excellent in workability, thereby providing the advantage that the manufacturing process can be simplified and a required component accuracy can be easily obtained.

[Patent Document 1] Japanese Patent Publication (Kokoku) No. H06-106028

[Patent Document 2] Japanese Laid-Open Patent Publication (Kokai) No. 2001-111128

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0007]

However, in the case of the latter ultrasonic

motor, the vibration plate 61 of the vibrator has the one and only out-of-plane bending vibration mode as a vibration mode in which it can be excited to generate vibrations, making it difficult to obtain a large force for feeding the driven member. In addition, since the areas of the vibration plate 61 in contact with the driven member 65 are very small areas or edges, it is difficult to provide a high accuracy for a shape and a flatness of the contact parts of the vibrator to define the parts.

[0008]

On the other hand, in the case of the former ultrasonic motor, the vibration plate 51 of the vibrator suffers neither the above-described problem of obtaining a sufficient output from an ultrasonic motor because it is excited in the two vibration modes, nor the above-described problem of the shape and flatness of the contact parts. However, in the vibration plate 51, the projections 52a and 52b are generally prepared from a material by machining and this machining cuts off significant portions of the vibration plate 51 other than the projections. Thus, the vibration plate 51 tends to have a deformation due to machining. In addition, it is difficult to provide the machined portions with a required accuracy. Furthermore, the existence of the projections 52a and 52b increases the size of the vibrator, reducing a power ratio to size,

which hampers designing the ultrasonic motor compact in size.

[0009]

It is an object of the present invention to provide a vibration wave driven apparatus that makes it possible to secure a required component accuracy obtained by machining and can increase a power ratio to the size of the apparatus.

[Means for Solving the Problems]

[0010]

To attain the above object, a vibration wave driven apparatus according to claim 1 is a vibration wave driven apparatus comprising: a driven member; and a vibrator consisting of an elastic member in contact with the driven member at a plurality of contact parts formed on one surface and an electromechanical conversion element of a flat plate-like shape joined to the other surface of the elastic member, characterized in that the plurality of contact parts are located on the same surface as the one surface of the elastic member.

[0011]

A vibration wave driven apparatus according to claim 2, in a vibration wave driven apparatus according to claim 1, is characterized in that the vibrator has a substantially rectangular plate-like shape, and the one surface has substantially the same shape and size as

the vibrator.

[0012]

A vibration wave driven apparatus according to claim 3, in a vibration wave driven apparatus according to claim 1 or 2, is characterized in that the elastic member is formed from a metal plate material by press punching or by an etching process.

[0013]

A vibration wave driven apparatus according to claim 4, in a vibration wave driven apparatus according to any one of claims 1 to 3, is characterized in that the electromechanical conversion element comprises a laminated piezoelectric element having piezoelectric materials and electrode materials alternately laminated one upon another.

[0014]

A vibration wave driven apparatus according to claim 5, in a vibration wave driven apparatus according to any one of claims 1 to 4, is characterized in that the elastic member includes notches or recessed parts for adjusting vibration characteristics of the vibrator formed therein at a plurality of locations thereof.

[0015]

A vibration wave driven apparatus according to claim 6, in a vibration wave driven apparatus according to any one of claims 1 to 5, is characterized in that the elastic member has a supporting member integrally

formed thereon, for supporting the vibrator.

[0016]

A vibration wave driven apparatus according to claim 7, in a vibration wave driven apparatus according to any one of claims 1 to 6, is characterized in that the electromechanical conversion element excites the vibrator in out-of-plane primary and secondary bending vibration modes having different directions from each other, and the plurality of contact parts are formed in a vicinity of loops of the primary bending vibration modes and in a vicinity of nodes of the secondary bending vibration modes.

[0017]

A vibration wave driven apparatus according to claim 8, in a vibration wave driven apparatus according to any one of claims 1 to 7, is characterized in that the contact parts have a space formed in a surface thereof opposed to the electromechanical conversion element.

[0018]

A vibration wave driven apparatus according to claim 9, in a vibration wave driven apparatus according to any one of claims 1 to 8, is characterized in that at least a part of the driven member is provided with a magnet.

[Advantages of the Invention]

[0019]

According to the vibration wave driven apparatus according to claim 1, a plurality of contact parts are located on the same surface as one surface of the elastic member. Hence, a required component accuracy obtained by machining can be easily secured. Further, projections are eliminated and hence the size of the vibrator can be reduced, whereby the power ratio to the size can be increased.

[0020]

According to the vibration wave driven apparatus according to claim 5, the elastic member includes notches or recessed parts for adjusting vibration characteristics of the vibrator formed therein at a plurality of locations thereof. Hence, it is possible to adjust a variation in the difference in the resonance frequency in the two vibration modes due to a variation in the thicknesses or the like caused during formation of the elastic member, thereby preventing the vibrator from having degraded vibration characteristics.

[0021]

According to the vibration wave driven apparatus according to claim 6, the elastic member has a supporting member integrally formed thereon, for supporting the vibrator. Hence, dissipation of the vibration energy attributable to the joint locations of components and a variation in the vibration characteristics, for example, can be suppressed.

[0022]

According to the vibration wave driven apparatus according to claim 8, the contact parts have a space formed in a surface thereof opposed to the electromechanical conversion element. Hence, an elastic characteristic is provided for the contact parts so that the contact parts can contact the driven member in a stable manner, thereby enabling efficient transmission of the vibration energy of the vibrator to the driven member.

[Best Mode for Carrying Out the Invention]

[0023]

The present invention will be described in detail with reference to the drawings showing an embodiment thereof.

[0024]

FIG. 1 is a schematic perspective view showing a vibration wave driven apparatus according to an embodiment of the present invention.

[0025]

The ultrasonic motor 1 in FIG. 1 is mainly comprised of a vibrator 2, and a slider 3 held in contact with the vibrator 2 while being pressurized by the vibrator. In addition to these components, the ultrasonic motor 1 also includes a flexible substrate for electrically connecting the vibrator 2 to an external device, a supporting member that supports the

vibrator 2, a guide member for the slider 3, and a pressurization mechanism for pressurizing the slider 3 against the vibrator 2. These components, however, are already known, and description thereof is omitted.

[0026]

The slider 3 is comprised of a square bar-like slider base part 31 formed of a magnetic material, and a plate-like friction member 32 that is joined to the slider base part 31 and is formed of a material having a high friction coefficient and a high friction durability. In the present embodiment, a martensite-based material SUS440C with its surface subjected to nitriding is used as the material of the friction member 32.

[0027]

The magnetic material constituting the slider base part 31 forms a magnetic circuit cooperatively with the ferromagnetic material SUS440C constituting the vibration plate 11. The friction member 32 generates a frictional force acting between the friction member 32 and the vibration plate 11 when the slider 3 is pressurized against the vibrator 2.

[0028]

The vibrator 2 is comprised of a rectangular flat plate-like elastic vibration plate 11 (elastic member) formed from a 0.15mm-thick plate material SUS440C that is a ferromagnetic martensite-based stainless steel, by

machining, and having a part of one surface thereof formed as contact parts 11-a (see FIG. 2) described later that are in pressure contact with the friction member 32 of the slider 3, and a piezoelectric element plate 12 (electromechanical conversion element) also having a rectangular flat plate-like shape and joined by bonding using an adhesive or the like to the other surface of the vibration plate 11, thus presenting a so-called unimorph structure. The entire vibration plate 11 has a substantially flat plate-like shape and hence can exhibit desired in-plane rigidity. Thus, the vibrator 2 can satisfy in-plane rigidity of the vibration plate 11 that the unimorph structure is required to have.

[0029]

FIG. 2 is a perspective view showing the vibrator 2 in FIG. 1.

[0030]

In the vibrator 2 of FIG. 2, the vibration plate 11 and the piezoelectric element plate 12 have shapes and positions thereof determined so that edges of the two members in the directions "X" and "Y" substantially coincides with each other. The vibrator 2 has a longer side of 5.5 mm, a shorter side of 3.1mm, and a thickness of 0.5mm.

[0031]

The vibration plate 11 has, on one surface thereof,

two contact parts 11-a and two edge parts 11-b constituting thicker parts, forming a lattice shape, and includes, at a portion of a region opposed to the slider 3, a thinner part 11-c as a recessed part provided at the center of the vibration plate 11 in the direction "X" and two thinner parts 11-d as recessed parts provided at both ends of the vibration plate 11 in the direction "X". The surfaces of the contact parts 11-a are flush with the surfaces of the edge parts 11-b. The two edge parts 11-b are not opposed to the slider 3. The vibration plate 11 is formed integrally with a supporting member, not shown, for supporting the vibrator 2.

[0032]

The two contact parts 11-a are disposed in the vicinity of the loops of a first vibration mode and in the vicinity of nodes of a second vibration mode (FIGS. 4), respectively. The vibration plate 11 is excited in the first vibration mode and the second vibration mode by the piezoelectric element plate 12.

[0033]

The vibration plate 11 is formed so as to be thin in the parts 11-c and 11-d subjected to etching processing. The thinner parts 11-c and 11-d have a thickness of 0.1 mm.

[0034]

The thinner parts 11-c and 11-d may be formed by

notching using press punching.

[0035]

FIG. 3 is a cross-sectional view taken along plane X-Z in FIG. 2, showing the vibrator 2 of FIG. 2.

[0036]

In FIG. 3, the piezoelectric element plate 12 is formed by a laminated piezoelectric element in FIG. 5, which will be described later. Alternatively, the piezoelectric element 12 may be formed by a bulk piezoelectric element.

[0037]

The piezoelectric element plate 12 is comprised of two activation parts 13-A and 13-B in the direction "X". When a predetermined electric field is applied to each of these activation parts 13-A and 13-B, the vibration plate 2 becomes deformed in a bent manner. Specifically, when alternating current signals near the resonance frequencies in the first and second vibration modes described later with reference to FIGS. 4 are applied to the respective activation parts 13-A and 13-B so that the phases of the alternating current signals are offset by 90° from each other, the vibrator 2 can be excited in the first and second vibration modes. Thus, the vibrations in the first vibration mode are substantially shifted by 90° from those in the second vibration mode.

[0038]

FIGS. 4 are diagrams useful in explaining the vibration mode in which the vibrator 2 in FIG. 1 is excited, and FIG. 4(a) shows the first vibration mode and FIG. 4(b) shows the second vibration mode.

[0039]

In FIG. 4(a), the first vibration mode is a primary out-of-plane bending mode in which one vibration node is generated along the direction "X" in the figure. In FIG. 4(b), the second vibration mode is a secondary out-of-plane bending mode in which two vibration nodes are generated along the direction "Y" in the figure. The shape of the vibrator 2 is selected so that these two vibration modes have substantially the same resonance frequency.

[0040]

When the vibrator 2 is exited in the first vibration mode, the two contact parts 11-a repeatedly make up-and-down motions in the direction "Z" in FIG. 4. When the vibrator 2 is exited in the second vibration mode, the two contact parts 11-a repeatedly make forward and backward motions in the direction "X" in FIG. 4. When excitations in the first and second vibration modes are carried out such that the respective vibration modes are shifted in temporal phase by 90° for example, the contact parts 11-a make substantially elliptic motions in the X-Z plane. With these substantially elliptic motions, a feeding force

is transmitted by the slider 3 disposed in pressure contact with the contact parts 11-a, in the direction "X" in FIG. 1 to move the slider 3 relative to the vibrator 2.

[0041]

The thinner parts 11-c and 11-d are recessed or lower in level than the contact parts 11-a. Thus, the thinner parts 11-c and 11-d do not interfere with the slider 3 and only the contact parts 11-a can contact the slider 3, whereby the desired feeding force can be transmitted to the slider 3.

[0042]

FIG. 5(a) to FIG. 5(g) are top plan views showing respective piezoelectric element films S1 to S7 in a laminated structure for the piezoelectric element plate 12 shown in FIG. 2.

[0043]

As shown in FIGS. 5, the piezoelectric element plate 12 is prepared as a laminated piezoelectric element by aligning and laminating the seven piezoelectric element films S1 to S7 in this order, and firing the laminated films. The piezoelectric element film S2 has electrode films S2-A, S2-B, and S2-S formed on one surface thereof. The piezoelectric element film S3 has an electrode film S3-G formed on one surface thereof. The piezoelectric element film S4 has electrode films S4-A and S4-B formed on one surface

thereof. The piezoelectric element film S5 has, on one surface thereof, an electrode film S5-G. The piezoelectric element film S6 has electrode films S6-A and S6-B formed on one surface thereof. The piezoelectric element film S7 has an electrode film S7-G formed on one surface thereof.

[0044]

The piezoelectric element film S1 has formed therein four through electrodes S1-HA, S1-HB, S1-HS, and S1-HG. The piezoelectric element film S2 has formed therein three through electrodes S2-HA, S2-HB, and S2-HG. The piezoelectric element film S3 has formed therein three through electrodes S3-HA, S3-HB, and S3-HG. The piezoelectric element film S4 has formed therein three through electrodes S4-HA, S4-HB, and S4-HG. The piezoelectric element film S5 has formed therein three through electrodes S5-HA, S5-HB, and S5-HG. The piezoelectric element film S6 has formed therein one through electrode S6-HG.

[0045]

The above through electrodes are formed through the respective piezoelectric element films in the thickness direction thereof so as to provide conduction for desired electrode films. Through electrodes of the piezoelectric element film S1 forming a surface layer are also used to provide conduction between the piezoelectric element plate 12 and an external circuit.

[0046]

The through electrode S1-HA provides conduction with the electrode films S2-A, S4-A, and S6-A. The through electrode S1-HB provides conduction with the electrode films S2-B, S4-B, and S6-B. The through electrode S1-HG provides conduction with the electrode films S3-G, S5-G, and S7-G. The through electrode S1-HS provides conduction with the electrode film S2-S.

[0047]

When the through electrode S1-HG is used as a common potential electrode and an alternating current potential is applied to the through electrode S1-HA, substantially a half of the piezoelectric element plate functions as the activation part 13-A (FIG. 3). When the through electrode S1-HG is used as a common potential electrode and an alternating current potential is applied to the through electrode S1-HB, substantially a half of the piezoelectric element plate functions as the activation part 13-B (FIG. 3). A sensor for monitoring the vibration state of the vibrator 1 is provided by detecting an output potential of the through electrode S1-HS with the through electrode S1-HG as a common potential electrode when the vibrator 1 is in a driven state.

[0048]

According to the ultrasonic motor 1 shown in FIG. 1, the surfaces of the contact parts 11-a are flush

with the surfaces of the edge parts 11-b, and thus a required component accuracy obtained by machining can be easily secured. Further, the vibrator has no projection and hence the size of the vibrator can be reduced, whereby the power ratio to the size of the ultrasonic motor 1 can be increased.

[0049]

Also according to the ultrasonic motor 1 shown in FIG. 1, the vibration plate 11 has substantially the same thickness over the entire range of the contact parts 11-a and the edge parts 11-b. Thus, the vibration plate 2 is formed by press punching a metal plate material or by an etching process, and the method of forming the vibration plate 2 can be selected.

[0050]

FIG. 6 is a cross-sectional view taken along plane X-Z in FIG. 2, schematically showing the structure of a first variation of the vibrator of FIG. 2.

[0051]

The vibrator 102 of FIG. 6 has substantially the same structure as that of the vibrator 2 of FIG. 2. Therefore, the same components as those of FIG. 1 are denoted by the same reference numerals and duplicate description thereof is omitted. Only components different from those of the vibrator 2 of FIG. 2 will be described below. This also applies to further variations described hereinafter.

[0052]

As shown in FIG. 6, the piezoelectric element plate 12 has a deactivation part 14 provided near the joint part with the vibration plate 11. With the vibration plate 11 and the piezoelectric element plate 12 integrally joined together, the vibration plate 12 and the deactivation part 14 act as in-plane rigidity parts required for the unimorph structure.

[0053]

The piezoelectric element plate 12 of the first variation is preferably formed of a laminated piezoelectric element. Specifically, the piezoelectric element film S7 of the laminated piezoelectric element shown in FIG. 5 is followed by a piezoelectric element film that has no electrode and acts as the deactivation part 14, thereby providing the structure of the piezoelectric element plate 12 shown in FIGS. 5.

[0054]

FIG. 7 is a schematic perspective view showing the structure of a second variation of the vibrator of FIG. 2.

[0055]

As in the case of the vibrator 2 of FIG. 2, the vibration plate 101 of the vibrator 202 of FIG. 7 is comprised of contact parts 11-a and edge parts 11-b. The lengths in the directions "X" and "Y" of the vibration plate 101 are shorter than those of the

piezoelectric element plate 12.

[0056]

According to the vibrator 202 of FIG. 7, the vibration plate 11 has a simple shape and thus can be manufactured more easily. Furthermore, the vibration plate 11 has a reduced area of joining to the piezoelectric element plate 12, and thus the amount of vibration energy absorbed by the adhesive can be reduced to improve the efficiency of the ultrasonic motor.

[0057]

FIG. 8 is a schematic perspective view showing the structure of a third variation of the vibrator of FIG. 2.

[0058]

The vibration plate 11 of the vibrator 302 of FIG. 8 includes compensation thinner parts 11-e that are provided at opposed longer sides of the thinner part 11-c, in two pairs or four locations. The compensation thinner parts 11-e each have the same thickness as that of the thinner part 11-c. The compensation thinner parts 11-e are formed from a metal plate material simultaneously with the thinner part 11-c by carrying out an etching process for example so as to remove unnecessary parts from the metal plate material.

[0059]

The compensation thinner parts 11-e are shaped

such that the frequency in the two vibration modes changes depending on the thicknesses of the two thinner parts 11-c and 11-e. In the third variation, the compensation thinner parts 11-e are formed at four positions substantially in the vicinity of the nodes of the second vibration mode so that the frequency change ratios of the two vibration modes to the thinner parts are the same.

[0060]

According to the vibrator 302 of FIG. 8, it is possible to adjust a variation in the difference in the resonance frequency in especially the two vibration modes due to a variation in the thicknesses caused during formation of the thinner parts, thereby preventing the vibrator 2 from having degraded vibration characteristics.

[0061]

FIG. 9 is a schematic perspective view showing the structure of a fourth variation of the vibrator of FIG. 2.

[0062]

In the vibration plate 11 of the vibrator 402 of FIG. 9, the contact parts 11-a each have a recessed part 11-a′ (FIG. 10) so as to form a space in a surface of the vibration plate 11 opposed to the piezoelectric element plate 12. As a result, the contact parts 11-a can provide an elastic characteristic in the direction

"Z" in FIG. 9 so that the contact parts 11-a can contact the slider 3 in a stable manner, thereby enabling efficient transmission of the vibration energy of the vibrator 402 to the slider 3. This elastic characteristic can be set to a desired value by selecting the thickness or size in the direction "X" of the contact parts 11-a.

[0063]

FIG. 11 is a schematic perspective view showing the structure of a fifth variation of the vibrator of FIG. 2.

[0064]

The vibration plate 11 of the vibrator 502 of FIG. 12 is formed integrally with a pair of supporting members 11-f of the vibrator 502 which protrude from the body of the vibration plate 11 in the direction "Y" in FIG. 11.

[0065]

According to the vibrator 502 of FIG. 12, the supporting members 11-f are formed integrally with the vibrator 502, thus suppressing dissipation of the vibration energy attributable to the joint locations of components and a variation in the vibration characteristics, for example.

[0066]

The supporting members 11-f may be formed simultaneously with the vibration plate 11 when the

vibration plate 11 is formed by press punching or an etching process, for example. This is suitable for mass production and provides a stable component accuracy, whereby the improved dimensional accuracy of the supporting members can suppress variations in characteristics caused by a state of support of the vibrator 502.

[Brief Description of Drawings]

[0067]

[FIG. 1] FIG. 1 is a schematic perspective view showing a vibration wave driven apparatus according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a perspective view showing a vibrator appearing in FIG. 1.

[FIG. 3] FIG. 3 is a cross-sectional view taken along plane X-Z in FIG. 2, showing the vibrator of FIG. 2.

[FIG. 4] FIGS. 4 are diagrams useful in explaining a vibration mode in which the vibrator 2 in FIG. 1 is excited, and FIG. 4(a) shows the first vibration mode and FIG. 4(b) shows the second vibration mode.

[FIG. 5] FIG. 5(a) to FIG. 5(g) are top plan views showing respective piezoelectric element films in a laminated structure for a piezoelectric element plate appearing in FIG. 2.

[FIG. 6] FIG. 6 is a cross-sectional view taken along plane X-Z in FIG. 2, schematically showing the structure of a first variation of the vibrator of FIG.

2.

[FIG. 7] FIG. 7 is a schematic perspective view showing the structure of a second variation of the vibrator of FIG. 2.

[FIG. 8] FIG. 8 is a schematic perspective view showing the structure of a third variation of the vibrator of FIG. 2.

[FIG. 9] FIG. 9 is a schematic perspective view showing the structure of a fourth variation of the vibrator of FIG. 2.

[FIG. 10] FIG. 10 is a cross-sectional view taken at line X-X in FIG. 9.

[FIG. 11] FIG. 11 is a schematic perspective view showing the structure of a fifth variation of the vibrator of FIG. 2.

[FIG. 12] FIG. 12 is a view useful in explaining the structure of a conventional ultrasonic motor.

[FIG. 13] FIG. 13 is a view useful in explaining the structure of another conventional ultrasonic motor.

[Description of Symbols]

[0068]

1 ultrasonic motor

2 vibrator

3 slider

11 vibration plate

11-a contact part

11-b edge part

11-c thinner part

11-d thinner part

11-e compensation thinner part

11-f supporting member

12 piezoelectric element plate

13A, 13B activation part

14 deactivation part

31 slider base part

32 friction member

[Title of the Document] Drawings

[FIG. 1]

[FIG. 2]

[FIG. 3]

[FIG. 4]

[FIG. 5]

[FIG. 6]

[FIG. 7]

[FIG. 8]

[FIG. 9]

[FIG. 10]

[FIG. 11]

[FIG. 12]

[FIG. 13]

[Title of the Document] Abstract

[Abstract]

[Problem to be Solved] To provide a vibration wave driven apparatus which makes it possible to secure a required component accuracy obtained by machining and can increase a power ratio to the size of the apparatus.

[Solution] An ultrasonic motor 1 is mainly comprised of a vibrator 2, and a slider 3 held in contact with the vibrator 2 while being pressurized by the vibrator. The slider 3 is comprised of a slider base part 31 formed of a magnetic material, and a friction member 32 that is joined to the slider base part 31. The vibrator 2 is comprised of an elastic vibration plate 11 having a part of one surface thereof formed as contact parts 11-a that are in pressure contact with the friction member 32 of the slider 3, and a piezoelectric element plate 12 joined by bonding using an adhesive or the like to the other surface of the vibration plate 11, thus presenting a so-called unimorph structure. The vibration plate 11 has, on one surface thereof, two contact parts 11-a and two edge parts 11-b constituting thicker parts, forming a lattice shape, and includes, at a portion of a region opposed to the slider 3, a thinner part 11-c as a recessed part provided at the center of the vibration plate 11 in the direction "X" and two thinner parts 11-d as recessed parts provided at both ends of the

vibration plate 11 in the direction "X". The surfaces of the contact parts 11-a are flush with the surfaces of the edge parts 11-b.

[Selected Drawing] FIG. 1

FIG. 1

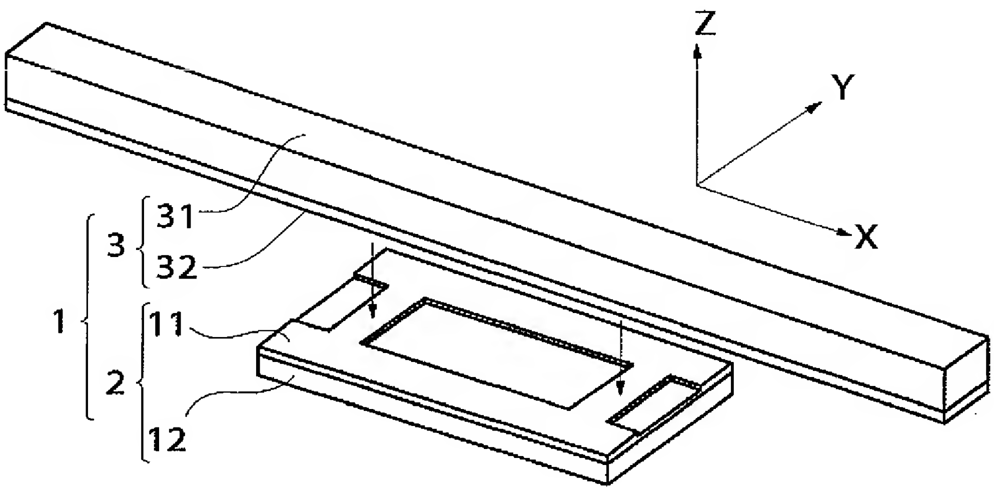


FIG. 2

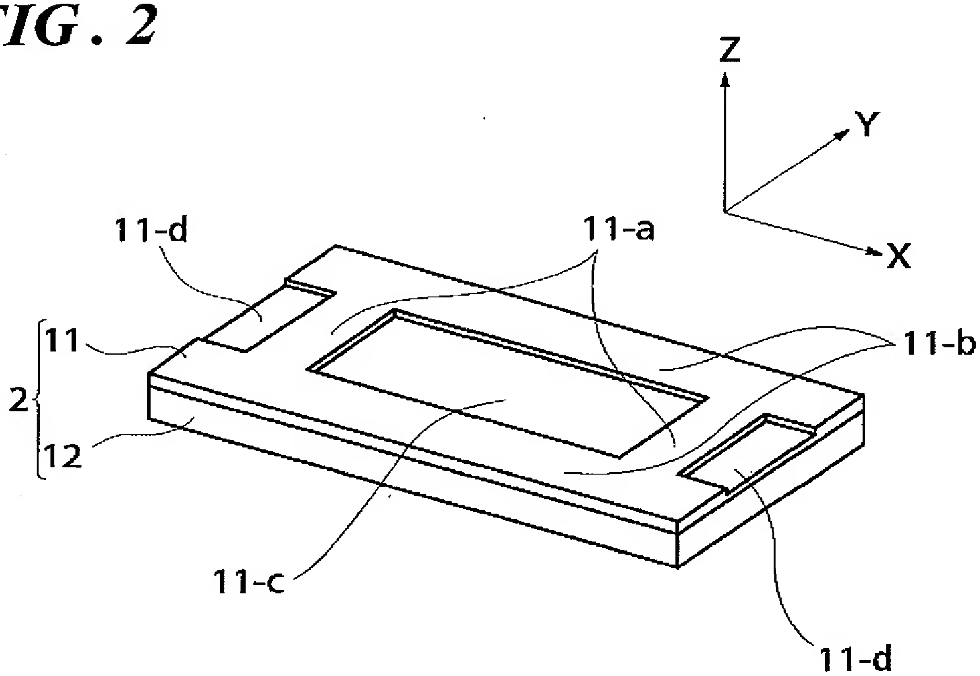


FIG . 3

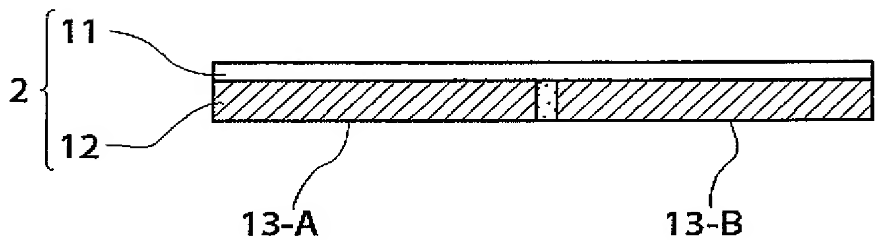
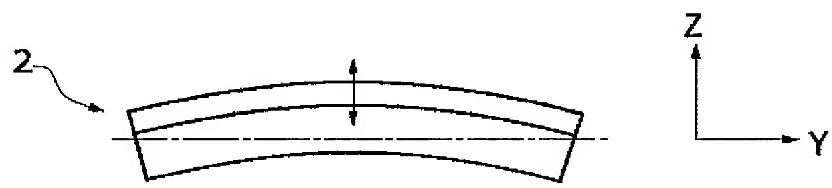
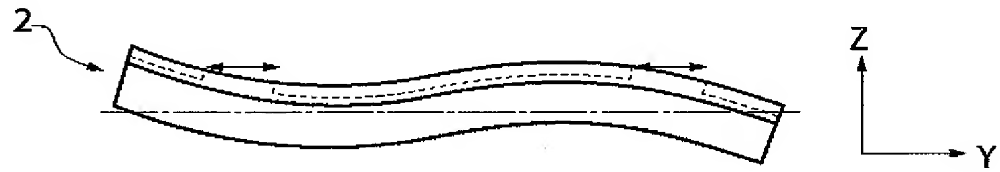


FIG . 4

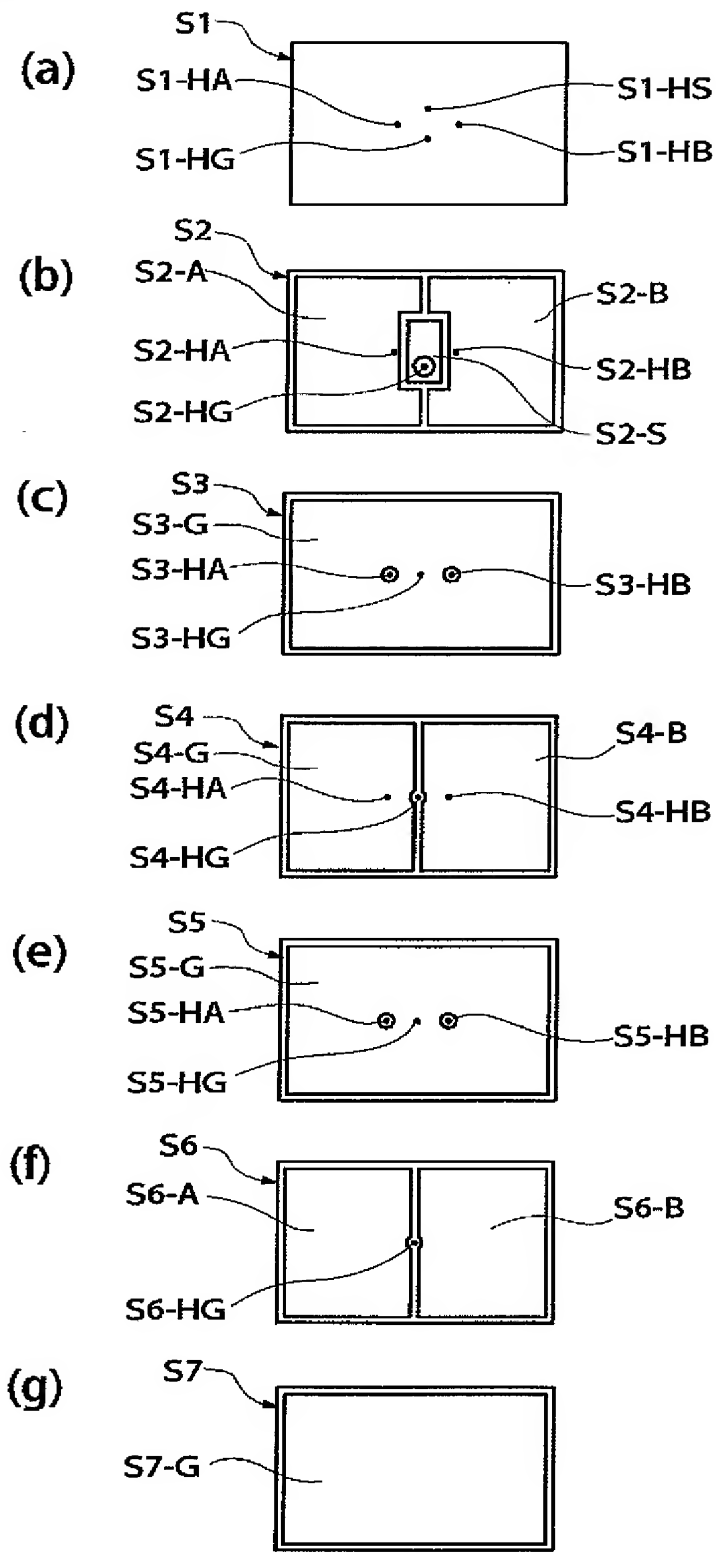


(a)



(b)

FIG. 5



(a)
S1
S1-HA
S1-HS
S1-HG
S1-HB
(b)
S2
S2-A
S2-B
S2-HA
S2-HB
S2-HG
S2-S
(c)
S3
S3-G
S3-HA
S3-HB
S3-HG
(d)
S4
S4-G
S4-B
S4-HA
S4-HB
S4-HG
(e)
S5
S5-G
S5-HA
S5-HB
S5-HG
(f)
S6
S6-A
S6-B
S6-HG
(g)
S7
S7-G

FIG. 6

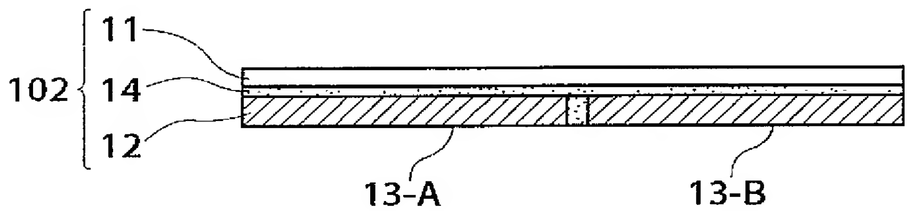


FIG. 7

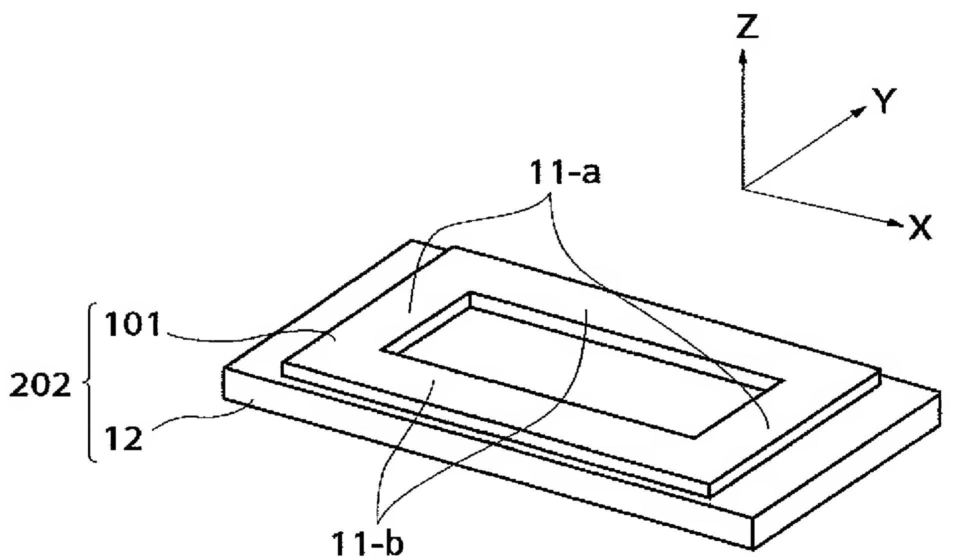


FIG. 8

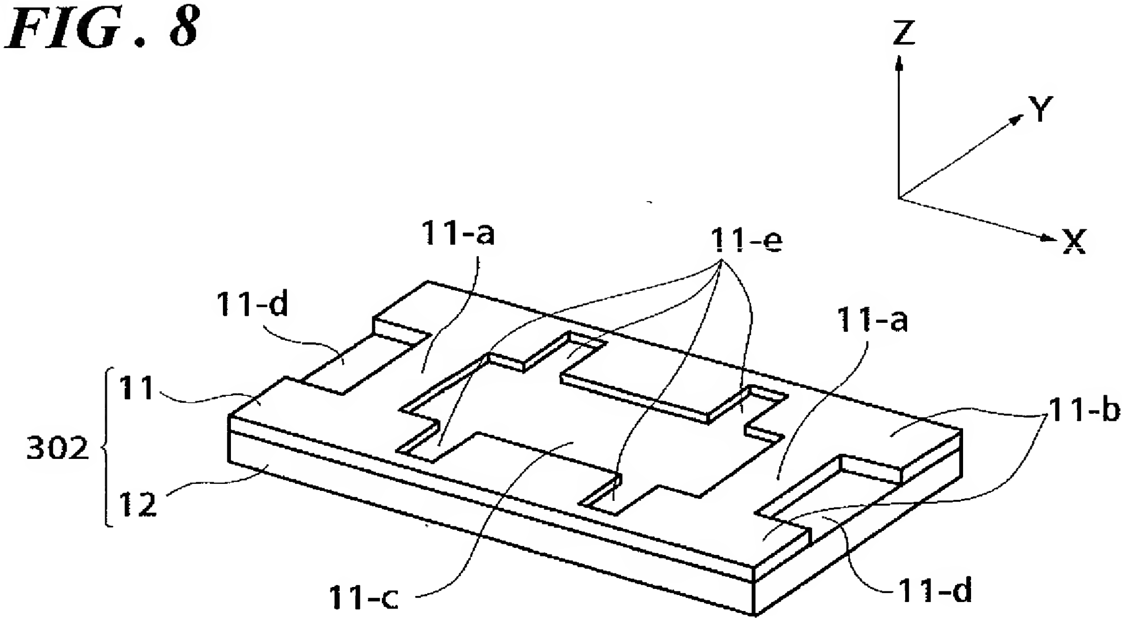

Z
Y
X
11-a
11-e
11-d
11-a
11
11-b
302
12
11-d
11-c

FIG. 9

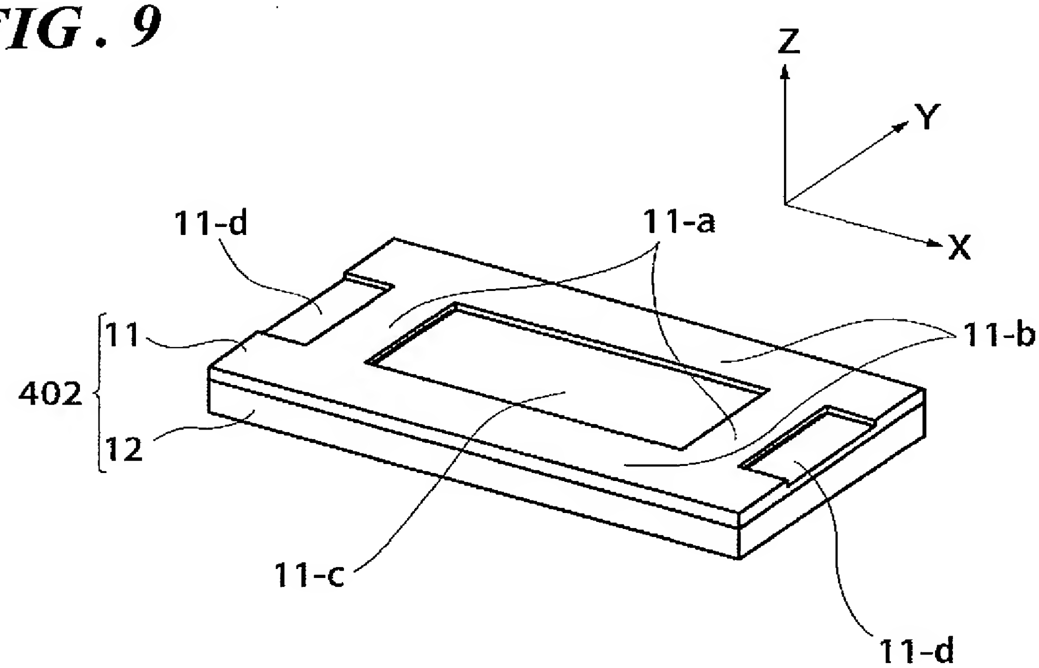

Z
Y
X
11-d
11-a
11
11-b
402
12
11-c
11-d

FIG. 10

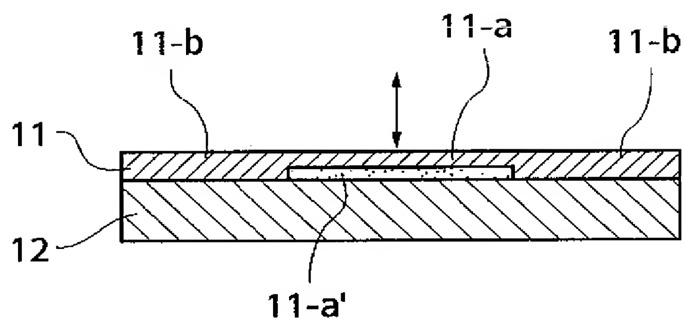

11-b
11-a
11-b
11
12
11-a'

FIG. 11

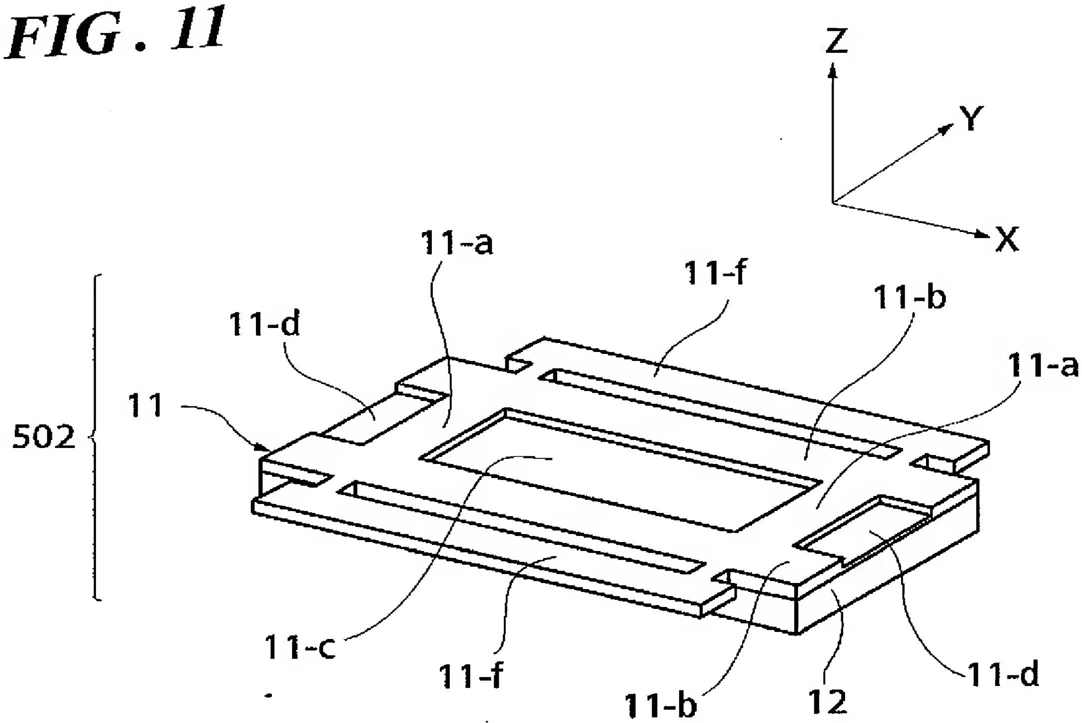

Z
Y
X
11-a
11-f
11-b
11-d
11-a
11
502
11-c
11-f
11-b
12
11-d

FIG. 12

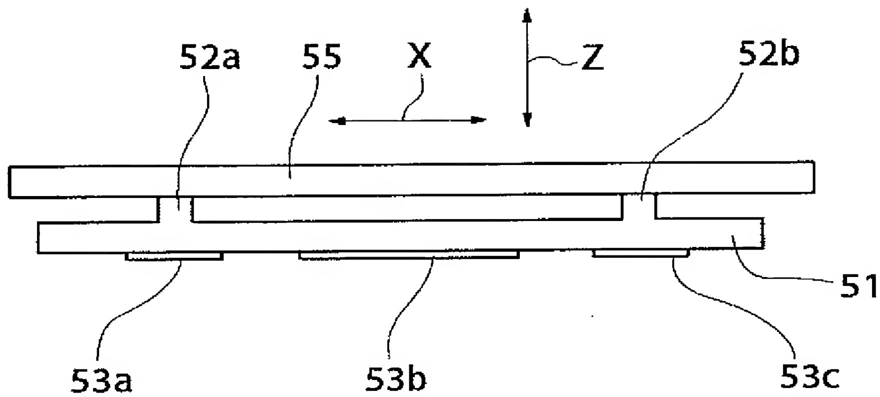


FIG. 13